

ANATOMICAL MODELS FOR VIRTUAL REALITY AND WEB-BASED APPLICATIONS

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Abstract- We present a methodology for the creation, manipulation and transmission of 3D anatomical models starting from stacks of medical images. The anatomical information for the models is first segmented from the images and then used by a surface reconstruction algorithm to create 3D meshes that accurately represent the surface of the organs being modeled. The meshes are then exported in an open format for manipulation in a graphics platform. Using high-end graphics algorithms we render and texture-map our meshes. We can also deform the meshes and assign physical and material properties to them. Our models can be used for virtual reality applications and can also be transmitted over the Internet for remote interactive visualization and retrieval.

Keywords - 3D Models, Java, VRML, X3D, Medical Web Applications, Medical Graphics, Visualization, Telemedicine

I. INTRODUCTION

In the past decades medical imaging systems such as CT and MRI have become widely used diagnostic tools for clinical diagnosis and medical scientific research. However, as household as these technologies have become, they remain expensive systems readily available only in radiology clinics. It is until recently, that the Internet, combined with powerful PC's, new graphics standards and web-based technologies have made previously restricted MR/CTI data available to everyone, even modest hospitals in small communities or rural areas. The Visible Human Project [1] was a landmark for widespread availability of radiological data. Current Internet 2 technology, combined with new specifications for the transmission of graphical data such as X3D and Lattice [2][3], offer promises that, in the short to medium term, not only images, but full 3D models, and even virtual reality scenarios and 3D medical simulators will be available over the Internet. Some authors [4][5], have already used web-based languages such as VRML and Java3D to create Internet available medical applications.

In this paper we present a methodology for the creation of accurate, realistic 3D anatomical models starting from a stack of 2D images. We use robust segmentation and reconstruction methods that have been developed in our lab in the past years [6][7] to go from 2D images to 3D meshes corresponding to the anatomical models. The anatomical models created can be exported in open format for its use in most graphical, CAD or modeling software. We are also able to transmit the models over the Internet using Java, VRML, and X3D technologies for remote users to visualize, manipulate and retrieve them for local use.

II. METHODOLOGY

A. Segmentation

We start the creation of our 3D models by segmenting a stack of 2D images. All of our models have been created by segmenting stacks of MR studies. Our segmentation algorithm identifies all the pixels from a particular anatomical structure inside an MR image. We work with information of 2 images at a time and assume that each distinct anatomical structure is represented by a relatively uniform gray level. With this simplified model of the MR images we achieve a very fast, practically automatic segmentation tool with only one parameter to adjust. The automatic segmentation of a stack of over 100 MR images of the brain is done in under 1 minute in a PIII PC. When the segmentation is interactively guided to achieve improved results, the visual interface that modifies the algorithm parameter allows the user to quickly improve the results and, in this case, the segmentation of a whole stack of 128 images takes roughly between 10-15 minutes when performed by an experienced user. A detailed description of the segmentation algorithm can be found in [6]. An example of the segmentation results used to build the anatomical models presented in this paper is shown in Fig.1.

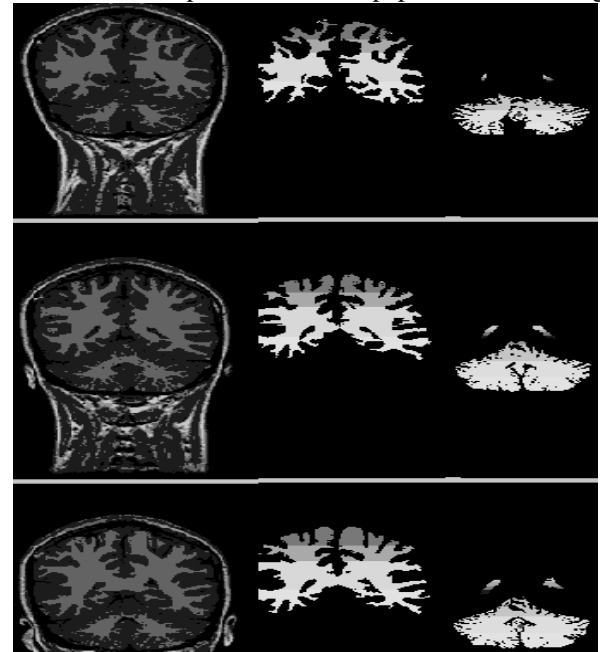


Fig. 1. Segmentation results of 3 non consecutive images. The original image is shown in the 1st column. Segmentation of the white matter, cerebellum and left and right ventricles are shown in the 2nd and 3rd columns.

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B. Reconstruction

We use a very robust 3D surface reconstruction algorithm developed in our lab and described in detail in [7][8]. The reconstruction algorithm takes as input the set of 3D points resulting from the segmentation of the stack of images and produces a 3D triangular mesh that closely approximates the real surface of the models. The reconstruction algorithm uses space partitioning, filtering and dynamical rules to build a detailed final mesh. The density of the mesh can be interactively adjusted by the user depending on the density of the set of points resulting from the segmentation and on the complexity of the surface to be reconstructed. This mesh can then be further simplified to eliminate triangles in areas of less detail to create compressed models that can then be used for remote and web-based applications. The details of the simplification algorithm are described in [9]. Some reconstruction examples are shown in Figs 2,3. The first column in Fig. 2 shows: a) the set of points produced after segmenting the cerebellum and ventricles from an MR study of the brain, b) the 3D mesh that reconstructs the surface of the set of points, and c) the rendered mesh. The second column of Fig. 2 shows the same results for the left and right ventricles. Fig. 3 shows 3 dense meshes corresponding to 2 pairs of ventricles and the white matter and different stages of mesh compression.

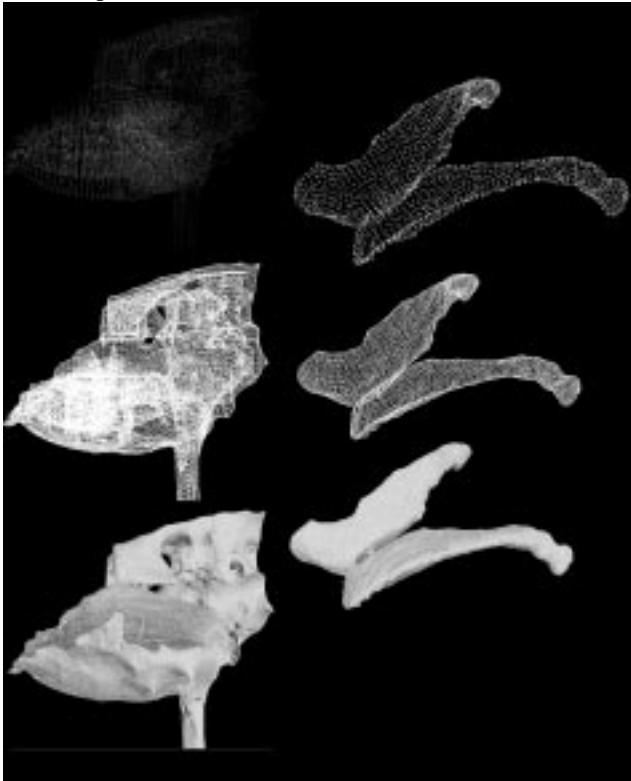


Fig. 2. Reconstruction of the cerebellum with ventricles attached and of the left and right ventricles alone.

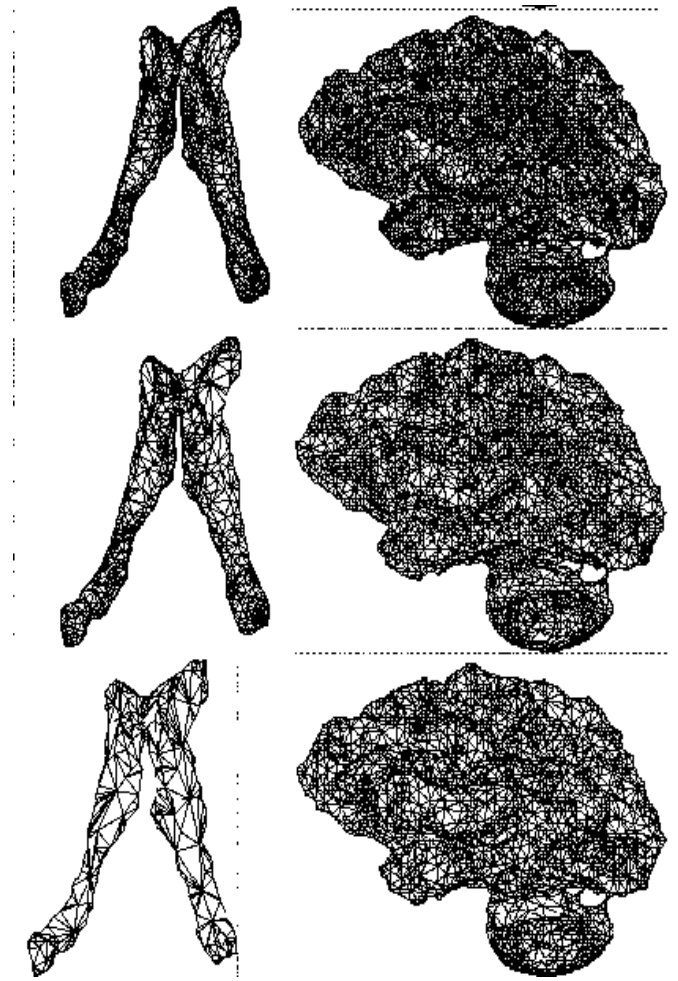


Fig. 3. 3D meshes corresponding to the ventricles and white matter with 3 different levels of mesh compression.

C. Graphical Production and Manipulation

The 3D meshes that result from the reconstruction process can be output in DXF or VRML format, making them suitable for manipulation by graphics packages. We use MayaTM, a high-end graphics software to render our 3D meshes with various material and lightning properties. We are also able to give our meshes physical properties to simulate dynamic phenomena. An interesting option in Maya is the possibility to interactively deform and render the meshes for applications such as cosmetic and reconstructive surgery or for matching and registration of information. We are also able to construct complex scenes containing several anatomical models as needed for the construction of atlases or virtual scenarios. Because of the physical properties of the models, they can interact with each other in a realistic way to simulate simplified surgical procedures or collisions as a result of an accident.

D. Web-based Application

The 3D anatomical models can also be transmitted over the Internet for remote interactive visualization and retrieval.

We use a VRML representation of the 3D meshes where we encode the information about vertices, triangles, normals, colors and texture coordinates. Using JavaScript we create a user interface for the user to interactively visualize the meshes and download the information for local use. Our current work includes integrating the recent graphics specification X3D and its Lattice extension (as proposed at the Web3D Consortium) to accelerate the transmission rate of our models in low band-width networks.

III. RESULTS

Some resulting anatomical models after rendering and texture mapping are shown in Fig. 4. Again, these results were produced from the segmentation and reconstruction of MR images. We show the model of the left and right ventricles, of the skull and of the white matter. In Fig.5 we show the possibility to render some models as semi-transparent in order to combine models and create anatomical atlases. We show the skull rendered with transparency and containing the ventricles inside. Fig. 6 shows a graphical manipulation of the models consisting of cutting the white matter in half to be able to analyse it from the inside as well as the outside of the model. This type of visualisation can be important when rendering artifacts create some ambiguity on the information that cannot be resolved by analysing just one side of the surface.

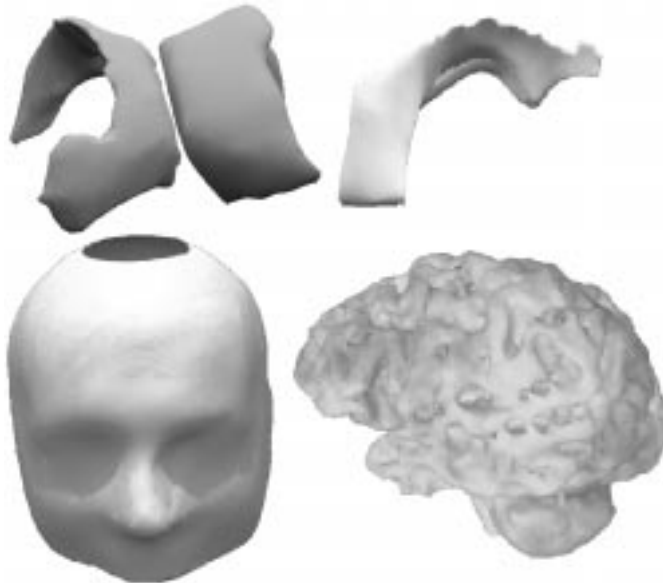


Fig. 4. Anatomical models corresponding to the ventricles, the skull and the white matter after rendering and texture mapping.

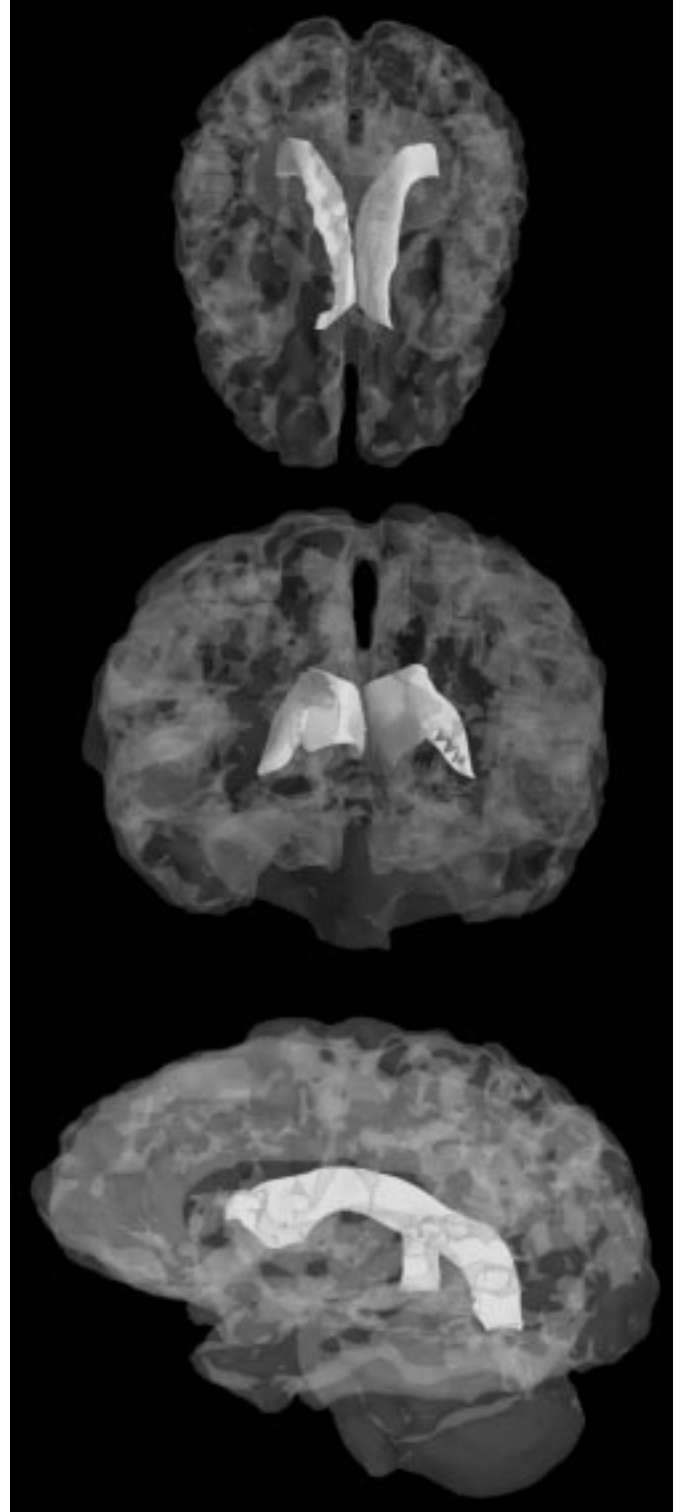


Fig. 5. Models rendered using transparency and superposition. We see a transparent white matter containing the ventricles inside.

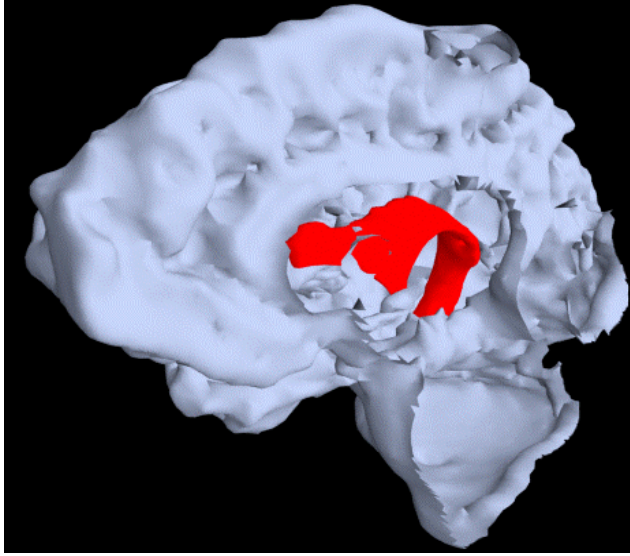


Fig. 6. The white matter cut in half in order to visualize the interior wall of the model and the interior organs (in this case a ventricle).

IV. DISCUSSION

For some years now, much work has been devoted to the creation of static 3D anatomical models and at least as much work to the simulation of deformations on the models. The possibility of creating 3D anatomical computer models as substitutes of real organs has seen big advances, but it is until recent years, that powerful graphical software and hardware driven mainly by the entertainment, games and animation industry have made it possible to have realistic medical simulators and medical virtual scenarios at our desktop. More and more, we are prone to encounter such graphical tools at the doctors office, but the possibilities of these new applications remain wide open and, most important, remain to be made available to a large audience of potential users.

Web-based applications make it possible to bring new and exciting graphics technology to remote locations for uses in all areas of Telemedicine. However, transmission of complex graphical information such as virtual scenarios, medical simulators, or simple anatomical data over the Internet using modems and low-band networks, remains still an unresolved technical challenge. Broad-band networks such as the Internet 2 initiative may be a solution, but remote applications are most needed in areas of low resources, so work on efficient transmission of medical information over the Internet is clue if these applications are to be available to everyone.

V. CONCLUSION

We propose in this paper a complete methodology for the creation, manipulation and transmission of 3D anatomical models starting from stacks of medical images. We use well-established segmentation and reconstruction algorithms previously developed by the authors and focus on the manipulation and transmission of the models. We use

Maya™ a high end graphics software to manipulate the models in a variety of ways: from simple rendering and texture mapping, to deformation, simulation of collisions and creation of complex virtual scenes containing multiple objects. We concentrate our current work in creating an efficient web-based application for the transmission of the models. We use VRML descriptions of the 3D anatomical models and JavaScript to create a web-user interface where the user can interactively visualize and retrieve the models over the Internet. We intend to migrate our model description to X3D in order to speed up the model transmission over low-band networks. Our application fits in various fields of use: from medical anatomical training, to the creation of medical virtual scenarios, graphics applications, clinical diagnosis and telemedicine.

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